Space Weather Technical Forecast

Issued on Sunday, 26 December 2021 at 01:05 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Slight chance of G1/Minor Storms on 27 December. Chance of M-class flares (R1/R2 Radio Blackout), with slight chance of X-class (R3 Radio Blackout).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been low over the past 24 hours, with numerous C-class flares observed. The majority of the activity remained near the southwest limb, where AR2907 Ehi/Beta rotated off the Earth-facing disc. This left 6 sunspot regions on the visible, including the recently developing AR2916 Ekc/Beta in the southeast quadrant. Despite its large size, this has not produced any notable flares in the last 24 hours. AR2818 in the northeast quadrant has also been showing some signs of development, but remains notably small than AR2816 and also with little significant activity. All other regions are currently small and simple.

No Earth-directed CMEs have been observed in available imagery.

Solar Wind / Geomagnetic Activity: Solar wind speeds as observed by DSCOVR at L1 have been slightly elevated at around 460 km/s, although a brief spike was observed at 25/0543 UTC to 500km/s, with a further drop at 25/2223 UTC to below 440 km/s. The density has been around average between these times, but below average before and after. Interplanetary magnetic field strength was weak at below 6nT, and whilst the north-south component was weak, it did become predominately negative (southward) peaking -5nT at 25/0714 UTC, before gradually rotating back to neutral. This very weak signal is potentially a weak transient passing, possibly related to the very late arriving CME from the 20th, however this attribution is low confidence. Phi angle was variable at first, but gradually become predominately negative (towards the Sun). Geomagnetic activity was Quiet (Kp 1-2).

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) remained at background levels. The high energy electron flux (greater than 2 MeV) was high until 24/2020UTC, reaching a peak of 2.02e3 pfu at 24/1715UTC. The associated 24-hour integrated fluence started above the Active threshold, but has declined through the 24 hour period. At 26/0000UTC it was 6.15e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low solar activity is forecast throughout the period, with a chance of M-class flares and a slight chance of X-class flares. This risk currently reduces to a slight chance of M-flares day 2 (27th), due to AR2907 rotating further away from the Earth-side, however any further development of AR2916 has the potential to elevate the flare risk again.

Solar Wind / Geomagnetic Activity: There are two potentially Earth-directed CMEs forecast, however both are currently expected to miss, with only weak glancing impacts at most. Slightly elevated solar winds are expected to ease day 1 (26th) before the arrival of the fast wind of coronal hole 37 day 2 (27th) with expected speeds of around 500km/s. This is likely to be followed by further fast wind from CH38 and CH39, leading to a broad period of slightly elevated to elevated solar winds. Mainly Quiet geomagnetic activity is forecast through days 1 (26th) with a chance of Active and a slight chance of G1/Minor Storms on day 2 (27th). Quiet to Unsettled

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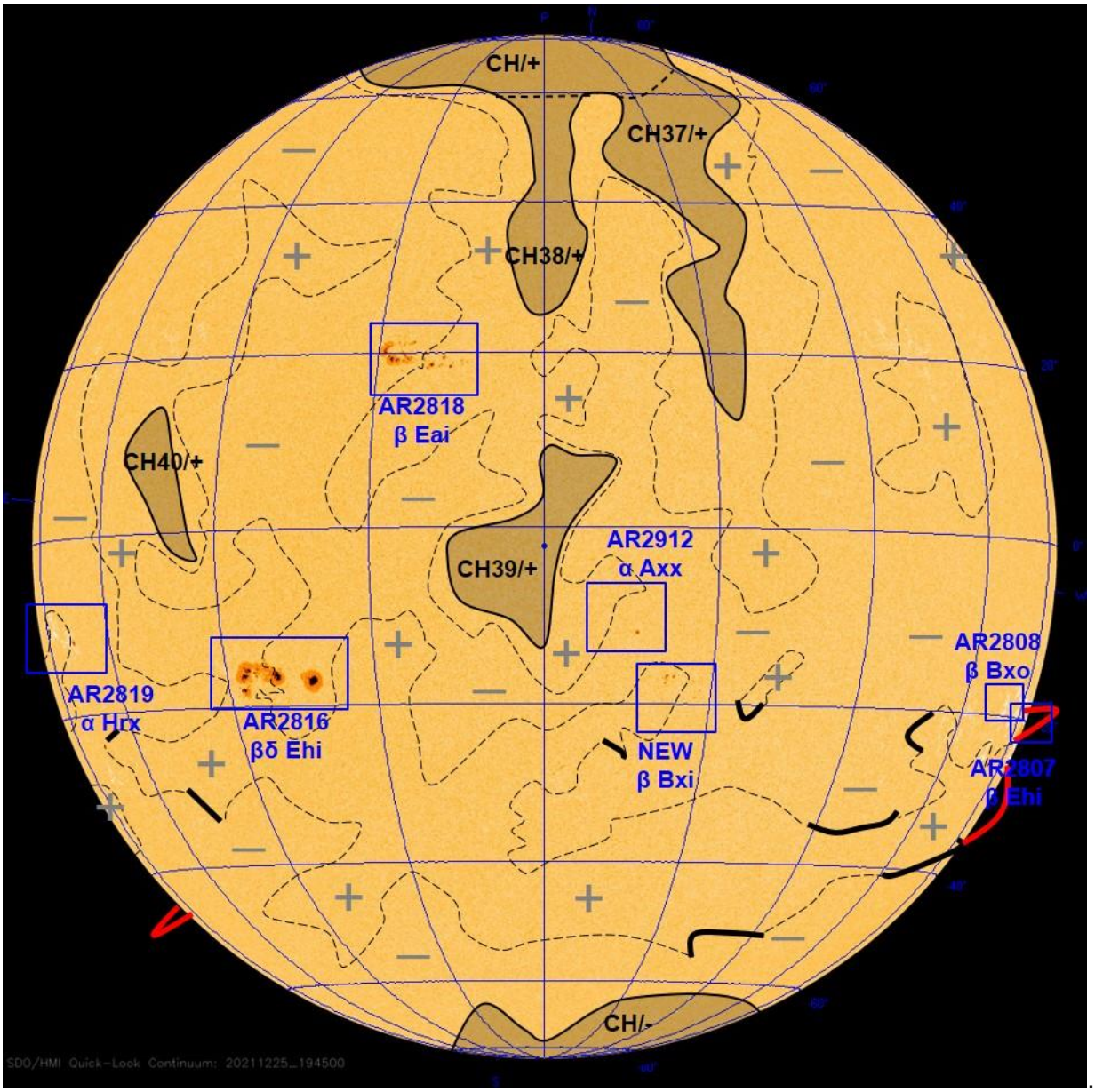
conditions with a chance of Active intervals then follows.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at background levels and below the S1 level, although there is a slight chance for some increased flux from any significant flare activity. High energy electron flux (greater than 2MeV) levels are forecast to fall to increasingly moderate levels, with a more significant fall to background on day 2 following any fast wind arrival. Electron fluence is expected to follow a declining trend for much of the period, below the Active (1e8 integrated pfu) threshold, but with a slight chance of rising above again by day 4.

Figure 1. Solar Analysis Valid 26/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There are two CMEs of current interest for the period, which left the Sun on 21 and 22 December respectively. These may glance the Earth on 26 or 27 December. However, as both were relatively narrow features, there is low confidence in this aspect of the forecast and they could miss entirely.

Coronal hole 37 fast wind is forecast to arrive at Earth on 27 December, with a small chance of an earlier arrival late on the 26th. This is a new feature on this rotation, with the recurrent feature from the previous rotation being coronal hole 38, which follows closely. This produced speeds of around 500km/s on the previous rotation and similar speeds are assumed on this rotation for either coronal hole. However confidence is low due to the northern location of CH37, and the lack of appreciable enhancements yet to be observed at STEREO A. Coronal hole 39 in the central disc is also new on this rotation, and is of a similar longitude to CH38, suggesting similar arrival times, either late day 3 or day 4. It is possible that once connected to the fast wind of CH37, a broad fast wind will be observed for the period, with enhancements from either CH38 or CH39 difficult to discern.

Geomagnetic activity is expected to be mainly Quiet day 1 (26th), with a chance of Active and a slight chance of G1/Minor Storm intervals later in the day and on day 2 (27th), due to the anticipated connection with the high speed stream from coronal hole 37. Quiet to Unsettled conditions with a chance of Active intervals then follows.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	5	20	10	5
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Name	Liftoff Time	Long	Lat	Radial Speed (km/s)	Half Angle	Time at 21.5Rs
CME-202112-016	22/12/2021 07:20	28W	22S	475	10	22/12/2021 17:35
CME-202112-015	21/12/2021 19:15	30W	20S	319	22	22/12/2021 07:26

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Figure 2: SDO aia-193 of previous rotation (left) and current rotation (right)

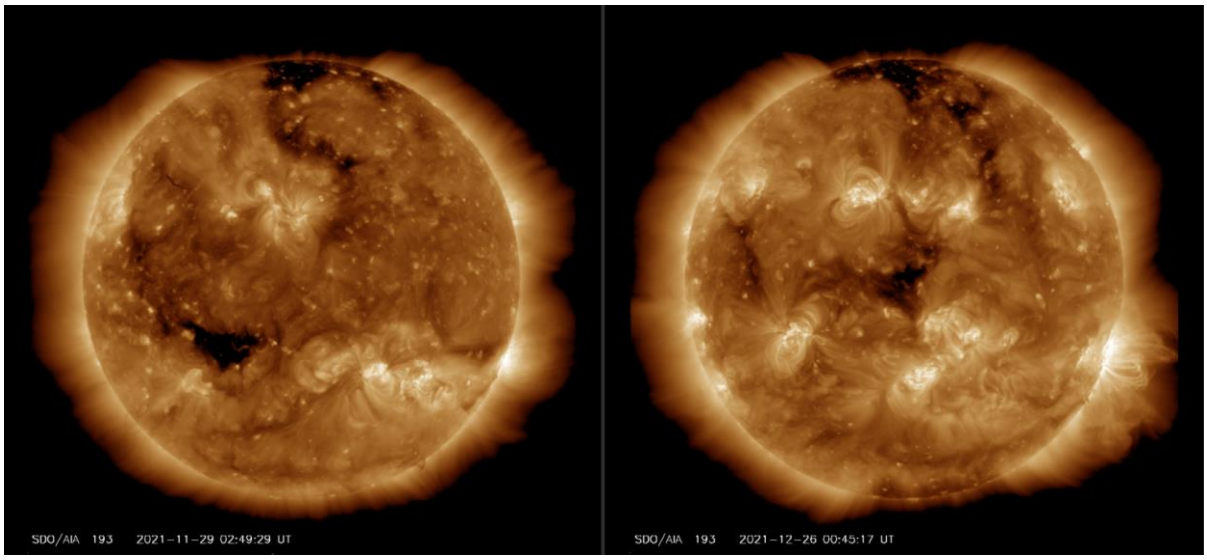


Figure 3: Solar Wind Persistence Model

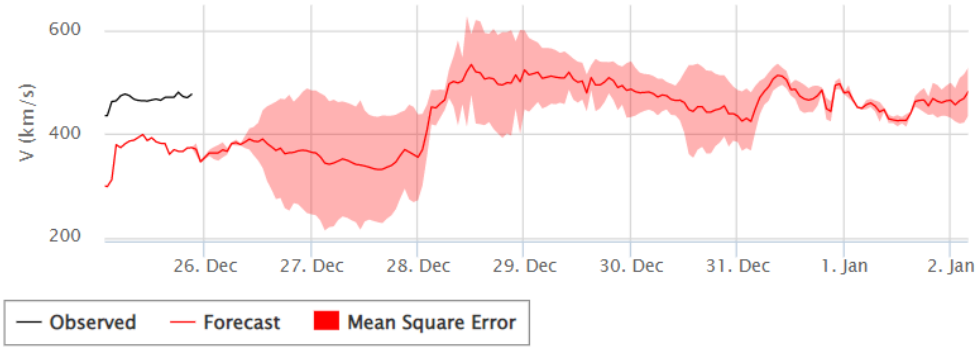
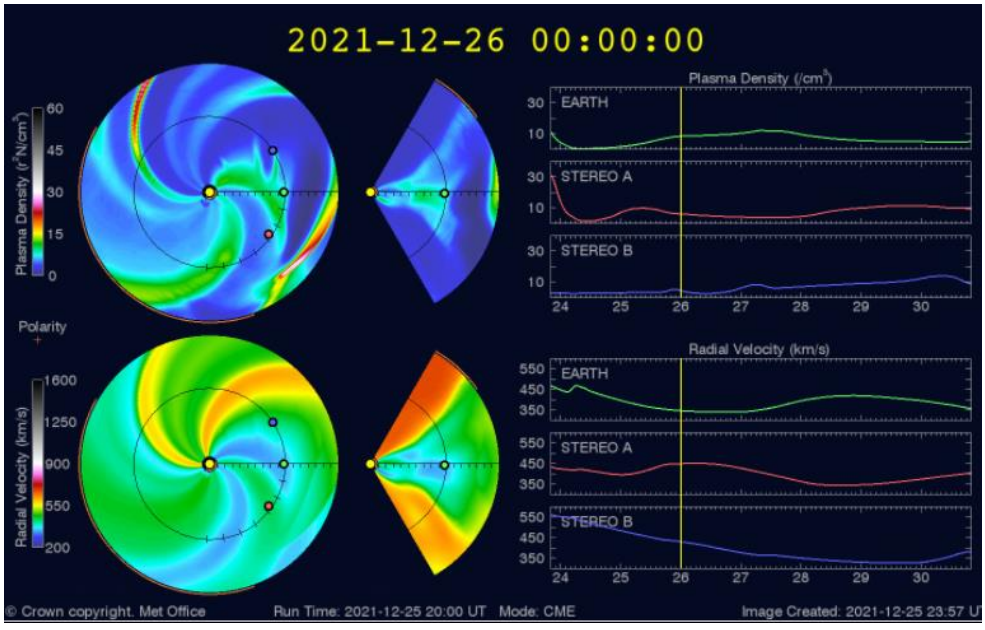


Figure 4: Enlil forecast speeds.



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Radio Blackouts - X-Ray Flares:

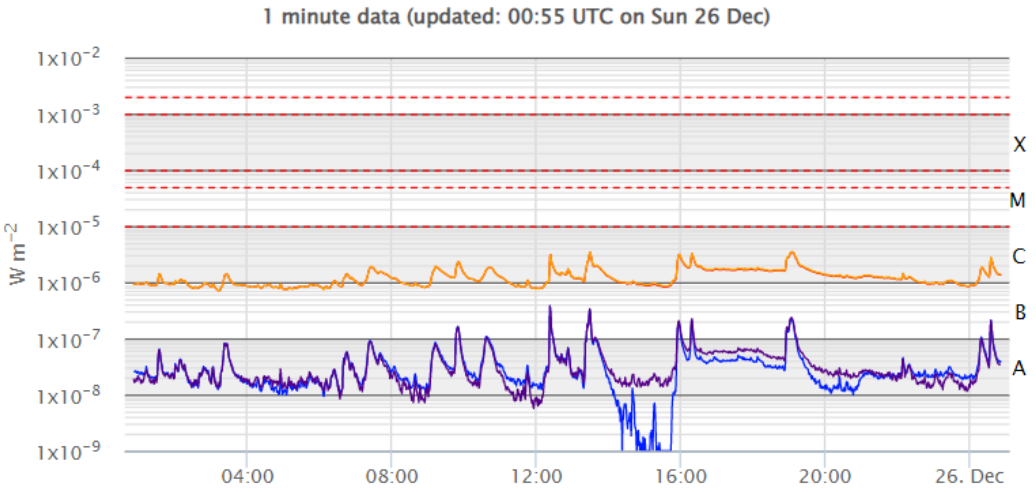
Solar Activity has been Low, with frequent small C-flares. There are 6 sunspot containing active regions on the disc. The most prominent is the large and still developing AR2916 Ekc/Beta. This region does have a history of producing M-flares, however this was on the 21st, when the region was still behind the limb, with no notable flares since. This region has developed a notable intermediate spot, essentially combining to form a large asymmetric trailer region with mixed polarity, giving the potential for delta spot development although currently umbra remain at least 2 degrees apart. This region will need to be monitored for any further development.

A further development region, AR2918 Dai/Beta is smaller, and with a simpler magnetic structure, despite being comprised of more numerous umbra regions compared to AR2916. This also has the potential for M-class flaring, and for further development. All other regions are currently small, and relatively simple. There also is still the potential for C and M-flares to be observed from AR2907 however, despite no longer being on the Earth-facing disc, positioned just over the eastern horizon.

Solar Activity is expected to Low, with a chance of rising to Moderate from any M-flares (R1/R2 radio blackout), and a slight chance of becoming High (R3 blackout) from any flaring of these regions. This risks falls slightly by day 2 (27th) as AR2907 rotates further away from Earth, but with an ongoing slight chance from AR2916.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	40	20	20	20
Very Active	R3 to R5 X Class	No	15	10	10	10

Figure 5: GOES-16/17 X-ray Flux



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Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10 MeV) as observed by GOES-16 is currently at background levels and expected to persist at these levels. There is a slight chance of these levels rising, however, from any notable flares from AR2916. AR2907 is still considered to be a potential region as a source for any proton storms as well, despite now being beyond the east-limb horizon, as any proton rich eruption could still be carried to Earth along the Parker Spiral.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 6: AR2816 and AR2818 Intensitygram and Magnetogram

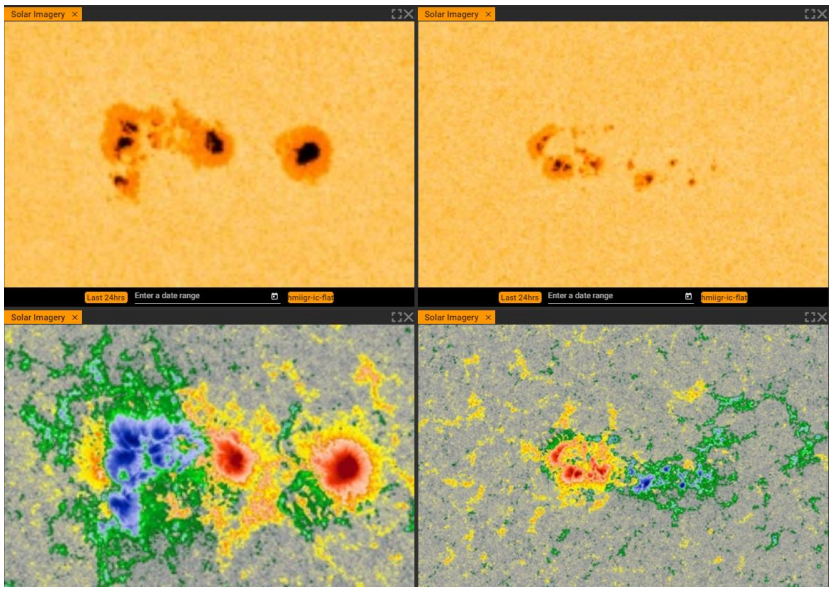
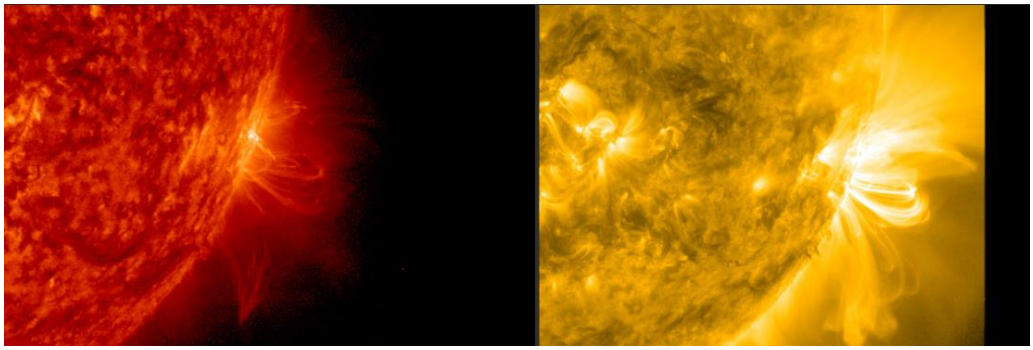


Figure 7: SDO aia-304 and aia-171 showing notable magnetic looping above AR2807, around the limb, with flaring still possible to observe from Earth-side



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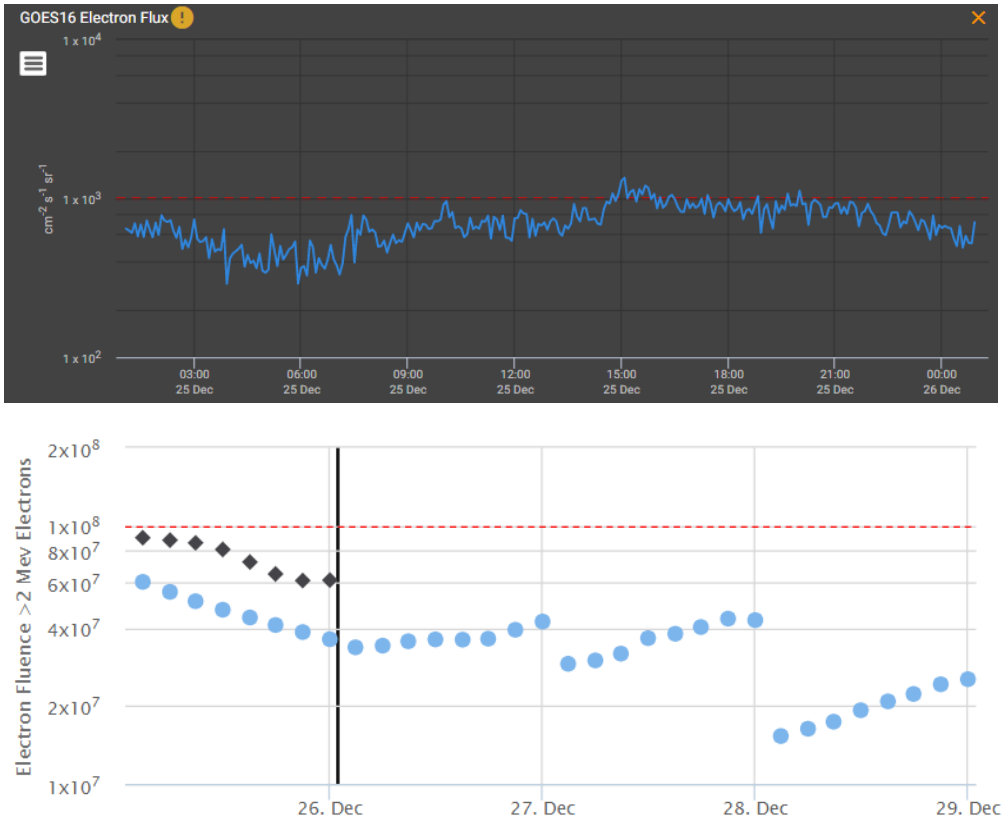
High Energy Electrons Event (≥ 2MeV):

The high energy (greater than 2MeV) electron flux, as observed by GOES-16, has been mainly moderate and gradually declining. Brief periods of high remain possible at diurnal max, however the arrival of the fast wind of coronal hole 37 day 2 (27th), and subsequently coronal holes 38 and 39 on day 3 (28th), could drop observed flux levels to background for a time, before a re-enhancement occurs as any compression of the radiation belts recedes. Moderate to High levels are then likely day 4 (29th).

The associated 24 hour fluence is forecast to persist below the Active threshold, with a declining trend. This is supported by REFM which is currently giving a good guide. Fluence levels are expected to rise from day 3 (28th) onward, in response to the increased flux, with a slight chance of rising above the Active threshold day 4 (29th)

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	10	20
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 8: GOES-16 >2MeV Electron Flux with associated Fluence and REFM.



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